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X-ray bursting neutron star atmosphere models using an exact relativistic kinetic equation for Compton scattering

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Abstract

Context. Theoretical spectra of X-ray bursting neutron star (NS) model atmospheres are widely used to determine the basic NS parameters such as their masses and radii. Compton scattering, which plays an important role in spectra formation at high luminosities, is often accounted for using the differential Kompaneets operator, while in other models a more general, integral operator for the Compton scattering kernel is used. Aims. We construct accurate NS atmosphere models using for the first time an exact treatment of Compton scattering via the integral relativistic kinetic equation. We also test various approximations to the Compton scattering redistribution function and compare the results with the previous calculations based on the Kompaneets operator. Methods. We solve the radiation transfer equation together with the hydrostatic equilibrium equation accounting exactly for the radiation pressure by electron scattering. We use the exact relativistic angle-dependent redistribution function as well as its simple approximate representations. Results. We thus construct a new set of plane-parallel atmosphere models in local thermodynamic equilibrium (LTE) for hot NSs. The models were computed for six chemical compositions (pure H, pure He, solar H/He mix with various heavy elements abundances Z = 1, 0.3, 0.1, and 0.01 Z, and three surface gravities log g = 14.0, 14.3, and 14.6. For each chemical composition and surface gravity, we compute more than 26 model atmospheres with various luminosities relative to the Eddington luminosity L Edd computed for the Thomson cross-section. The maximum relative luminosities L/L Edd reach values of up to 1.1 for high gravity models. The emergent spectra of all models are redshifted and fitted by diluted blackbody spectra in the 3-20 keV energy range appropriate for the RXTE/PCA. We also compute the color correction factors f c. Conclusions. The radiative acceleration g rad in our luminous, hot-atmosphere models is significantly smaller than in corresponding models based on the Kompaneets operator, because of the Klein-Nishina reduction of the electron scattering cross-section, and therefore formally "super- Eddington" model atmospheres do exist. The differences between the new and old model atmospheres are small for L/L Edd < 0.8. For the same g rad/g, the new f c are slightly larger (by approximately 1%) than the old values. We also find that the model atmospheres, the emergent spectra, and the color correction factor computed using angle-averaged and approximate Compton scattering kernels differ from the exact solutions by less than 2%. © 2012 ESO.

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Keywords

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